Lubrication Solutions for Space Mechanisms

LUBRICANTS.
TECHNOLOGY.
PEOPLE.

FUCHS

MOVING YOUR WORLD

MOVING YOUR WORLD
by reaching for the stars

Nye Lubricants, a member of the FUCHS Group, has formulated high-quality, lubrication solutions for the space industry for more than 65 years. We work with design engineers in the private, government, and military sectors to formulate specialty lubrication solutions for next-generation spacecraft. Launch vehicles, rovers, satellites, and applications involved in human travel and space exploration are just a few of the examples that require greases and oils that can withstand the demanding operating conditions of space.

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Advantages of Specialty Lubricants for Space Mechanisms

The durability and reliability of all space mechanisms, including their lubrication, is critical to ensure the success of long-range missions. These missions will include exposure to ultra-high vacuum, radiation, and extreme temperatures, making higher performance and extended life lubricants a requirement.

Mechanisms

GYROSCOPES

OPTICS

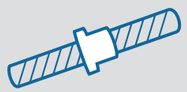
REACTION WHEELS

SOLAR ARRAY DRIVES

Components

BEARINGS

GEARS



BALL & LEAD SCREWS

ELECTRICAL INTERCONNECTS

Wide-Temperature Performance

Our lubrication solutions for space mechanisms can withstand extreme temperatures with minimal changes in viscosity. Our perfluoropolyether (PFPE) lubricants can withstand temperatures from –90 °C to +250 °C. Our multiply-alkylated cyclopentane (MAC) lubricants have an operating range of -50 °C to 125 °C and offer an unmatched wear protection. If a space application requires the low outgassing and excellent wear performance of a MAC lubricant and the operating temperature is below -50 °C, some engineers add a heater to their design that raises the temperature into the operating temperature range of MACs.

Improves Wear & Load Capacity

Lubricants with good film strength are recommended for space applications and ensure moving parts are coated to minimize contact and friction. MAC lubricants are known for resisting wear-related break down to protect components under heavy loads.

Extends Component Life

Components in space mechanisms are expected to offer the highest reliability. As the ability to service or replace these components is limited or non-existent, lubricants must be able to protect components for the entirety of their intended life. We offer ‘Lube-for-Life’ lubricants, meaning that they have long-life performance to ensure reliability for the entirety of your mission.

Reduces Outgassing

Outgassing is akin to evaporation; it is the release of small fractional molecules from a bulk liquid or solid material. Evaporation losses accelerate when operating in vacuum and compromise a lubricant’s integrity over time. Low outgassing lubricants have a lower material loss to ensure longer-lasting lubrication.

Outgassed molecules can also condense on surfaces and adversely affect the optical or surface properties of the material onto which it condenses. Condensation on optical components like sensors, lenses, and solar cells can compromise mission performance. Lubricant outgassing is measured in total mass loss (TML) and collected volatile condensable materials (CVCM) per ASTM E595. The lubricants we offer for these components are tested to this standard and fall well below the acceptable outgassing limits determined by the space industry.

Reduces Particle Generation

Dynamic particle generation happens when contaminants are created by being forced or expelled from a lubricated ball-screw, bearing, or gear system into the operating environment. These contaminants could include base oil constituents, thickener particles, additives, etc. and are freed from the grease through rolling, sliding, or a combination of both. Our proprietary test method and apparatus allows us to measure particle generation under these dynamic conditions.

Aerospace Satellites

Our lubricants are designed specifically for satellite components that must survive the severe conditions of the space environment, where long life is critical for the success of the mission.

1. Camera Optics

To ensure contaminants from other lubricants do not creep onto the camera lens, NYEBAR® can be applied to multiple mechanisms on the camera mast. NYEBAR® creates a barrier film, holding the lubricating oil in place. Ultrafiltered MAC lubricants have low outgassing rates and superior anti-wear performance, making them ideal for components within or near a satellite camera. Lubricants with a lower particle generation count will ensure that optical components are not compromised.

Bearings - RHEOLUBE® 2000LO & RHEOLUBE® 2004LO
Camera Mast - NYEBAR® Barrier Film

2. Reaction Wheel

By providing attitude control, reaction wheels are the control gyros for satellites. A medium viscosity MAC grease will operate through high-torque adjustments and can withstand extreme temperatures.

Barrier Film - NYEBAR® Barrier Film
Bearings - RHEOLUBE® 2000

3. Scan Mirror Assembly

This system moves in a horizontal motion to scan targeted areas for imaging. Lubricating the bearings within the assembly will reduce vibration, and allow the system to move in a quick, smooth motion.

Bearings - SYNTHETIC OIL 2001-3PBNP

4. Spin Mechanism Assembly

This instrument supports and spins the satellite throughout the mission. The bearings within the assembly are in constant rotation and require a MAC grease fortified for friction reduction.

Angular Contact Bearings -
RHEOLUBE® 2000 & SYNTHETIC OIL 2001

5. Solar Array Drive

This system is responsible for positioning the solar panels in order to harvest sun light that can be turned into energy. MAC lubricants fortified with both anti-oxidants and anti-wear additives will help ensure long life of components.

Harmonic Gear Drive -
RHEOLUBE® 2004 & SYNTHETIC OIL 2001-3PB

Slip Ring in Power Transfer Assemblies -
RHEOLUBE® 2001

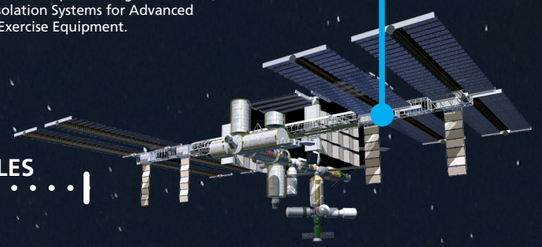
Success Stories: Lubricants in Space

250 MILES

International Space Station (ISS)

Devices: Multiple Mechanisms
Products: Various products including RHEOLUBE® 2000

Multiple devices for positioning and control; Vibration Isolation Systems for Advanced Resistance Exercise Equipment.

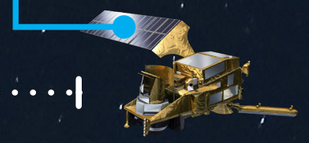


516 MILES

MetOp-SG A & B

Devices: Multiple Instruments
Product: SYNTHETIC OIL 2001A

This partnership between ESA and EUMETSAT is developing the next generation of weather satellites.

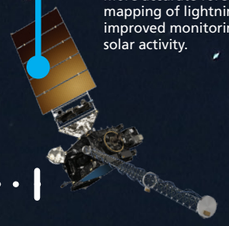


22,300 MILES

GOES-R Series

Devices: Reaction Wheels & Solar Array Drives
Products: SYNTHETIC OIL 2001-3PB and RHEOLUBE® 2000 & 2004

This joint effort between NASA and the NOAA aims to provide more accurate forecasts, real-time mapping of lightning activity, and improved monitoring of solar activity.



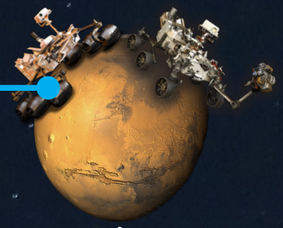
34 - 249,000,000 MILES

Mars Curiosity & Perseverance Rover

Device: Mast Camera
Product: NYEBAR® Barrier Film

Mars Rover Curiosity has provided photos along with data concerning climate and geology since August 2012.

The Mars Perseverance Rover will provide opportunities to gather knowledge that addresses the challenges of future human expedition to Mars.



438 MILES

Thermal Infrared Sensor (TIRS)

Device: Angular Contact Bearings
Products: RHEOLUBE® 2000 and SYNTHETIC OIL 2001

The Thermal Infrared Sensor located on the Landsat Data Continuity Mission (LDCM) measures land surface temperature.

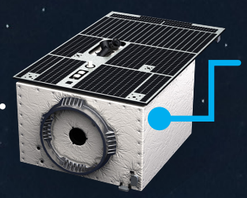
160 MILES

405 MILES

EnMap

Device: Shutter Calibration Mechanism Gear
Product: RHEOLUBE® 2000

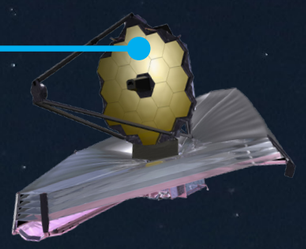
This German hyperspectral satellite mission aims to monitor and characterize the Earth's environment on a global scale.



James Webb Space Telescope (JWST)

Devices: Multiple Mechanisms
Product: Custom MAC Oil

The James Webb Space Telescope will be a large infrared telescope with a 6.5 meter primary mirror. The telescope will be launched on an Ariane 5 rocket from French Guiana.

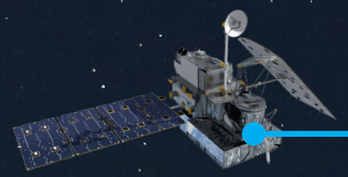


253 MILES

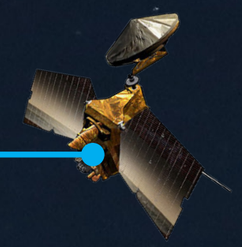
Global Precipitation Measurement (GPM)

Device: Harmonic Drive Gear
Products: RHEOLUBE® 2004 & SYNTHETIC OIL 2001-3PB

Global Precipitation Measurement is a joint mission between JAXA and NASA that records precipitation characteristics on Earth.



1,000,000 MILES



Mars Climate Sounder (MCS)

Device: Actuator
Product: SYNTHETIC OIL 2001A

The Mars Climate Sounder observes the temperature, humidity, and debris content of the Martian atmosphere.

55 - 217 MILES

CubeSats/NanoSats

Device: Reaction Wheels
Products: MAC Formulations and NYEBAR® Barrier Film

The reaction wheels located on CubeSats/NanoSats provide an efficient, high performance solution for attitude control.

Testing Capabilities

Our lubrication solutions for space are tested and validated for their performance in our state-of-the-art laboratory dedicated to in-vacuum testing. In this laboratory lubricants can be tested under simulated environmental operating conditions (i.e., vacuum, extreme temperatures) and provide our customers with performance data that helps them understand how our lubricants will perform in their application. Ultimately, this service helps our customer make the most informed lubricant choice.

Friction & Wear

SRV Tribometer
The SRV (Oscillating, Friction & Wear) test rig can run custom tests with options that include: rotational and linear oscillatory motion, tests up to 2,000 N load, 2,000 RPM, and a maximum temperature of 180 °C. Specimens include ball on disc, pin on disc, cylinder on disc, and custom geometries.

Mini Traction Machine (MTM)
The Mini Traction Machine (Figure 2) measures friction in a mixture of rolling/sliding contacts to simulate applications like rolling element bearings and gears. The MTM allows for the speed element to be a combination of sliding and rolling speed to produce the entrainment speed. The MTM provides a very good testing method for scuffing and galling of metal surfaces by allowing for the ball and disc to be driven in different directions (contrarotation). This produces a tribological test that can operate with high sliding / rolling speeds and low entrainment speed.

Relative Life

Spiral Orbit Tribometer
Originally developed by NASA, the Spiral Orbit Tribometer (SOT) produces relative lifetime calculations based on the number of orbits made below a friction level which is normalized to the amount of lubricant on the ball bearing. The testing (Figure 1) is done in ultra-high vacuum and simulates a thrust bearing. The results indicate the lubricant consumption, degradation, and life.

Vacuum Bearing Test Rig
Data from the Vacuum Bearing Test rig can determine the life expectancy of our lubricants on angular contact bearings in high vacuum environments. This rig can support customer supplied bearings to simulate how a lubricant will perform in a specific application. Our high vacuum test can assess performance at temperatures up to 200 °C and determine mass loss under specific operating conditions. The rig also uses electrical resistance across the bearing to determine which lubrication regime (boundary, mixed or elasto-hydrodynamic) our products qualify under, given the test parameters.

Cleanliness

Particle Generation
The Dynamic Particle Generator is used to classify lubricant particle generation into ISO and Federal cleanliness levels. It utilizes an ISO 3 clean air system, precision ball screw, and particle counter to characterize the number of particles down to 0.1 micron produced by various greases as the test is run.

Outgassing
Outgassing testing (per ASTM E595 Vacuum Stability) screens materials for volatile contamination. This test provides percent Total Mass Loss (TML) and percent Collected Volatile Condensable Materials (CVCM) data for our lubricants. Residual Gas Analysis can be used to determine the elemental species contained in the outgassing material. This testing provides customers with an understanding of the stability of our materials in a static vacuum environment and identifies which materials are outgassing.

Vapor Pressure
The Knudsen method is used to determine a lubricant's vapor pressure (VP) and requires a very small sample, reducing testing costs and efficiency. The sample is placed in a small, capped cell with an orifice in the cap of known diameter. The cell is then placed in one of the vacuum chambers, at a desired temperature and duration. The mass loss from the lubricant is factored into the Knudsen equation, along with the other known variables of temperature and time, to calculate the Knudsen VP of that material at that temperature.

Figure 1: Spiral Orbit Tribometer

Figure 2: Mini Traction Machine

Synthetic Oil & Greases for Space Mechanisms

MAC vs. PFPE

Our space oils and greases are formulated using two different base oils: Perfluoropolyethers (PFPE) and multiply-alkylated cyclopentanes (MAC), each offering specific benefits.

MAC
Unlike other lubrication solutions on the market, MAC lubricants alone offer the unique combination of extreme wear protection, low outgassing, and additive compatibility for optimal performance in space applications.

PFPE
If your application requires low outgassing and an extremely wide operating temperature range but does not require the extreme wear performance or specialized additives of a MAC lubricant, a PFPE from our NYETORR® or NYECLEAN® product line is recommended.

We have developed PFPE lubricants using the most advanced technology available, like NYETORR® 6350EL, which offers significantly improved load-carrying ability and much longer operating life versus heritage PFPE technology.

Synthetic Oil for Space Mechanisms

Product Name	Temperature Range (°C)	Base Oil Chemistry	Base Oil Viscosity ASTM D445 (cSt)			Pour Point (°C)	Evaporation CTM-2 (24 h, 100 °C) (wt%)	Vacuum Stability ASTM E595 (125 °C, 7 x 10-3Pa, 24 hrs) (wt%)		Vapor Pressure Knudsen (25 °C) (Torr)	Density (g/cc^{-3})	SRV Coefficient of Friction & Wear ASTM D5707 (100N, 50Hz, 1 stroke, 2 h, 40 °C)		Particulate Cleanliness Levels* IEST-STD-CC-1246D
			-40 °C	40 °C	100 °C			TML	CVCM			CoF	Wear Scar (mm)	
SYNTHETIC OIL 1001	-50 to 125	MAC	24,910	55	8	-59	0.06	2.23	1.064	5.49×10^{-11}	0.85	0.11	0.44	Level 50
SYNTHETIC -OIL 1001A	-50 to 150	MAC	26,070	56	9	-63	0.02	0.25	0.242	1.27×10^{-11}	0.85	0.16	0.62	Level 50
SYNTHETIC OIL 1001-3PB	-50 to 125	MAC	24,910	56	8	-59	0.06	0.30	0.066	2.45×10^{-10}	0.85	0.14	0.91	Level 50
SYNTHETIC OIL 2001	-45 to 125	MAC	80,494	107	14	-55	0.04	1.39	0.700	1.88×10^{-10}	0.84	0.11	0.43	Level 50
SYNTHETIC OIL 2001A	-45 to 125	MAC	80,500	108	15	-55	0.00	0.12	0.013	4.50×10^{-11}	0.84	0.19	0.80	Level 100
SYNTHETIC OIL 2001B	-45 to 125	MAC	80,500	108	15	-55	0.10	0.94	0.574	8.18×10^{-12}	0.86	0.11	0.43	Level 50
SYNTHETIC OIL 2001-3PB	-45 to 125	MAC	80,500	108	15	-55	0.10	0.33	0.293	1.27×10^{-10}	0.86	0.11	0.48	Level 50
NYETORR® 6201	-45 to 150	MAC	80,500	108	15	-55	0.00	0.11	0.010	6.91×10^{-11}	0.84	0.18	0.80	Level 50
NYETORR® 6301	-75 to 250	PFPE	5,818	187	56	-80	0.00	0.00	0.002	2.79×10^{-12}	1.83	0.08	0.84	Level 25
NYETORR® 6351	-65 to 250	PFPE	13,380	186	45	-69	0.04	0.00	0.000	4.43×10^{-13}	1.84	0.10	0.64	Level 25

Synthetic Grease for Space Mechanisms

Product Name	Temperature Range (°C)	Base Oil Chemistry	Base Oil Viscosity ASTM D445 (cSt)			Thickener Type	NLGI Grade ASTM D217	Oil Separation ASTM D6184 (24 h, 100 °C) (wt%)	Evaporation (24 h, 100 °C) (wt%)	Vacuum Stability ASTM E595 (125 °C, 7 x 10-3Pa, 24 hrs) (wt%)		Vapor Pressure Knudsen (25 °C) (Torr)	Density (g/cc^{-3})	SRV Coefficient of Friction & Wear ASTM D5707 (100N, 50Hz, 1 stroke, 2 h, 40 °C)		Low Temperature Torque ASTM D1478 (g.cm, -40 °C)		Ultrafiltration Cleanliness Levels* (10-34 µm, particles/cc)	Dynamic Particle Generation CTM-094	
			-40 °C	40 °C	100 °C					TML	CVCM			CoF	Wear Scar (mm)	Starting	10-min run		1200 RPM	2400 RPM
RHEOLUBE® 1000	-50 to 125	MAC	24,910	53	8	Sodium Soap	2	0.3	0.20	2.307	0.635	1.79×10^{-11}	0.84	0.11	.040	2,079	494	< 500	ISO 3.9	ISO 4.4
RHEOLUBE® 1000-3PB	-50 to 125	MAC	24,910	53	8	Sodium Soap	2	1.4	1.90	1.820	0.208	1.02×10^{-9}	0.89	0.11	0.53	4,793	658	< 500	ISO 4.0	ISO 6.0
RHEOLUBE® 2000	-45 to 125	MAC	72,000	110	15	Sodium Soap	2	3.3	0.10	2.461	0.729	1.79×10^{-10}	0.89	0.11	0.41	265	126	< 500	ISO 4.0	ISO 6.0
RHEOLUBE® 2000B	-45 to 125	MAC	72,000	110	15	Sodium Soap	2	5.0	0.10	2.117	0.647	8.18×10^{-12}	0.89	0.11	0.40	2,581	601	< 500	ISO 4.0	ISO 6.0
RHEOLUBE® 2004	-45 to 125	MAC	72,000	110	15	Sodium Soap	2	0.1	0.10	1.873	0.104	8.46×10^{-10}	0.89	0.11	0.51	4,941	778	< 500	ISO 4.0	ISO 6.0
RHEOLUBE® 2004LO	-45 to 125	MAC	72,000	110	15	Sodium Soap	2	0.1	0.10	0.772	0.268	2.45×10^{-10}	0.89	TBD	TBD	TBD	TBD	< 500	TBD	TBD
RHEOLUBE® 3000-3PB	-10 to 125	MAC	N/A	2,082	202	Sodium Soap	2	1.0	TBD	TBD	TBD	TBD	0.89	TBD	TBD	TBD	TBD	TBD	TBD	TBD
NYETORR® 6200	-45 to 150	MAC	77,000	108	15	PTFE	1	3.5	0.00	0.058	0.025	2.44×10^{-11}	1.05	0.12	0.46	1,135	599	< 300	ISO 3.6	ISO 4.3
NYETORR® 6300	-65 to 250	PFPE	5,818	187	56	PTFE	2	4.8	0.02	0.036	0.006	2.79×10^{-12}	1.89	0.11	0.68	221	125	< 300	ISO 4.2	ISO 5.1
NYETORR® 6350EL	-80 to 250	PFPE	13,380	200	47	PTFE	2	6.3	0.06	0.060	0.008	5.76×10^{-12}	1.89	0.16	0.76	545	271	< 400	ISO 3.9	ISO 4.5

*CTM = Company Test Method *Level 25 = 1 25µm particle max. Level 50 = 1 50µm particle max. Level 100 = 1 100µm particle max*CTM = Company Test Method

FUCHS Lubricants

Innovative lubricants need experienced application engineers

Every lubricant change should be preceded by expert consultation on the application in question. Only then the best lubricant system can be selected. Experienced FUCHS engineers will be glad to advise on products for the application in question and also on our full range of lubricants.

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